Image Enhancement using Bright Pass Filter (BPF)

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Abstract: **This paper presents an algorithm for Image enhancement. This algorithm deals with the Bright-pass filter (BPF) which decomposes an image into Illumination and Reflectance. This BPF is implemented with and without using Block processing. The Bi-log transformation is applied on the illumination component and then it is synthesized with reflectance which results in the final enhanced image. Both the results of this algorithm with and without using Block processing in comparison with Brightness Preserving Dynamic Histogram Equalization (BPDHE) algorithm are presented.**

Index Terms: Image Enhancement, Bi-log transformation, Block processing.

I. INTRODUCTION

The principle objective of Image enhancement is to process an image so that the result is more suitable than the original image for specific applications. Up to now, Image enhancement has been applied to varied areas of science and engineering, such as Atmospheric sciences, Astrophotography, Biomedicine, Computer vision, etc.

The enhancement methods can broadly be divided in to the following two categories. They are Spatial domain methods, which operate directly on pixels. Frequency domain methods, which operate on the Fourier transform of an image.

A literature survey [1-16] on Image enhancement techniques is done by referring to the research work done during 2000-2014. The several number of methods are available in image enhancement such as processing an image by decomposing the image based on specific criteria, using the filter or a group of filters, modifying the multi-scale measure, constructing HDR image with multiple images, using different transformation methods, etc.

The image enhancement techniques differ by their features. Some of them are enhancing the low contrast or medium contrast details, images whose contrast details vary across the image, only a part of the image or different parts of the image to different extents, simultaneously both contrast and sharpness of the image and integrating the luminance and contrast masking phenomena.

The Block processing function helps to process the image individually on each block by dividing the original image into rectangular blocks of required size specified by the two-element block-size vector. After processing, the results are assembled into an output image. In this algorithm, the block-size is taken as 15*15.

II. BRIGHT-PASS FILTER

Many algorithms result in over-enhancement since they do not consider the range of reflectance. Hence the BPF [15] was considered. This filter is mainly used to restrict the range of reflectance to [0], [1]. In the BPF, the effect on the central pixel of value b caused by an adjacent pixel of value a is positively related to the frequency for pixels of value a and pixels of value b being neighbours all over the image.

In general, the neighbours can be defined flexibly for different applications. In the BPF, the weight of adjacent pixels is considered as its normalized version as the frequency is static. The neighbours are considered since it was already known that there is no obvious difference between the filtering results by using slightly different neighbours. The filtering results obtained using four-connectivity and eight-connectivity are similar. For ease, the neighbours of a pixel G(x, y) in four connectivity was given as:

$$NB(x,y) = \{G(x, y-1), G(x, y+1), G(x-1, y), G(x+1, y), G(x, y)\} \quad (1)$$

The frequency Q'(k, l) for pixels of values k and l to be neighbours all over the image is given as:

$$Q'(k,l) = \sum_{x=1}^{m} \sum_{y=1}^{n} NN_{k,l}(x,y) \quad (2)$$

where $NN_{k,l}(x, y)$ indicates the number of its neighbours of value l, m and n are the height and the width of the image.

The frequency signal $Q'(k, l)$ suffers from noise and varies roughly. The local mean $Q(k, l)$ of the frequency signal is considered:

$$Q(k,l) = \left(\sum_{i=l-win}^{i=l+win} Q'(k,i)\right)/(2.win+1) \quad (3)$$

where win is the window size. The size of the window should not be too small or too large, to remove the noise as well as preserve the local trend of the frequency. The range of the gray levels was used to set the size of the window. The window size is set as follows:

$$win = (\max(G(x, y)) - \min(G(x, y)))/32 \quad (4)$$

The bright-pass filter, BPF[·], is defined as the weighted average of adjacent pixels with the weight positively related to the frequency $Q(k, l)$ and is evaluated as follows:

$$BPF[G(x,y)] = \frac{1}{W(x,y)} . \sum_{(i,j)\in\Omega} (Q(G(x,y), G(i,j)). U(G(i,j), G(x,y). G(i,j))) \quad (5)$$

where Ω denotes the local patch of size 15*15 centered at coordinate (x, y). To ensure that only brighter neighbours are taken into account, the unit step function $U(x, y)$ is utilized and $W(x, y)$, the normalization factor ensures the sum of pixel weight to be 1.

$$W(x,y) = \sum_{(i,j)\in\Omega} (Q(G(x,y), G(i,j)). U(G(i,j), G(x,y))) \quad (6)$$

Image Decomposition:

BPF is used here to evaluate the illumination. The reflex lightness is termed as the product of reflectance and illumination according to the Retinex theory. Illumination means light cast on the surface of the scene. Reflectance means surface reflects more than light than it receives.

$$I^c(x, y) = R^c(x, y) \cdot F(x, y) \quad (7)$$

where $I^c(x, y)$ is the lightness of the colour channel c, $R^c(x, y)$ is the corresponding reflectance, and $F(x, y)$ is the illumination.

In many cases, the resulting illumination will be darker than the reflex lightness since most of the Retinex algorithms are using Gaussian or Bilateral filters to evaluate the illumination which means it results in reflecting more light than it receives i.e., reflectance is more than 1.

In BPF, the illumination is evaluated by assuming it as the local maxima for each pixel. Only the neighbours that are brighter than the central pixel are considered. Illumination can be evaluated by using the equation below:

$$L_r(x,y) = \frac{1}{W(x,y)} . \sum_{(i,j)\in\Omega} \left(Q(L(x,y), L(i,j)). U(L(i,j), L(x,y). L(i,j))\right) \quad (8)$$

Since already the illumination has been obtained, the reflectance can be driven by removing illumination from the reflex lightness:

$$R^c(x, y) = I^c(x, y)/L_r(x, y) \quad (9)$$

The Fig.1 shows an example of image decomposition through the BPF. From the Fig.1, it can be said that the reflectance image presents the details whereas the illumination image presents the ambience of incident light.

Fig.1. Example for Image Decomposition: (a) Original image (b)Illumination image (c)Reflectance image.

III. BI-LOG TRANSFORMATION

Bi-log transformation is made use of here to perform action mainly on low frequency information i.e., the negative frequency components present in the considered image. The region near zeros are to be highlighted for enhancement and brightness preservation. Hence, the region around zeros are enhanced by using this transformation. The region around zeros are enhanced by using this transform. The transform should not suppress the details so that it should be bright enough and meanwhile the lightness order should be preserved.

The experimental results show that the log shape gives good results for several images. The shape is given by the equation.

$$Lg(x, y) = \log(L_r(x, y) + \varepsilon) \quad (10)$$

where $L_r(x,y)$ is an illumination image, ε is a small positive constant and is empirically set as 1.

In histogram specification, the intensity of the processed images appears similar even the input images looks slightly different based on their intensities. The illumination can be enhanced bright enough by making use of log shape histogram specification. According to the gray-level distribution of input illumination, the difference is represented by slightly increasing the pixels of lower gray-level. The log of the image is taken as the weight of the histogram which performs well. The weighted histogram, mp(k), was considered.

$$mp(k) = \frac{\sum_{i=0}^{m}\sum_{j=0}^{n} Lg(I,j).\ \delta(Lr(i,j),k)}{\sum_{i=0}^{m}\sum_{j=0}^{n} Lg(i,j)} \quad (11)$$

$$\delta(x, y) = \begin{cases} 1, \text{ for } x = y \\ 0, \text{ else} \end{cases} \quad (12)$$

where δ is an impulsive function. The modified histogram considers the values of the gray-levels along with the numbers of pixels into consideration.

The Cumulative Density Function (CDF) of the weighted histogram is given from the definition of CDF:

$$cL(v) = \sum_{k=0}^{v} mp(k)$$

$$= \sum_{i=0}^{m} Lg(i,j)U(v, Lr(i,j)) / \sum_{i=0}^{m}\sum_{j=0}^{n} Lg(i,j) \quad (13)$$

$$U(x,y) = \begin{cases} 1, \text{ for } x >= y \\ 0, \text{ else.} \end{cases} \quad (14)$$

Similarly, the CDF of the specified histogram, s(z), is defined as follows:

$$cf(z) = \sum_{i=0}^{z} s(i) / \sum_{i=0}^{255} s(i) \quad (15)$$

$$s(z) = \log(z + \varepsilon),\ z \in N[0, 255] \quad (16)$$

where z is a non-negative integer within [0, 255], ε is a small positive constant.

As per histogram specification, definition needs the purpose of BLT where values of z satisfies.

$$cf(z_v) = cL(v), \text{ for } v = 0, 1, 2, \ldots, L-1 \quad (17)$$

The values of z_v is given by

$$z_v = cf^{-1}[cL(v)], \text{ for } v = 0, 1, 2, \ldots, L-1 \quad (18)$$

The final enhanced image is given by:

$$L_b(x, y) = cf^{-1}[cL(L(x, y))]$$
$$\text{for } v = 0,1,2, \ldots, L-1 \quad (19)$$

IV. SYNTHESIS OF REFLECTANCE AND MAPPED ILLUMINATION

Although the drastic changes in illumination is one of the drawback for illumination to display details, illumination is compulsory for preserving the naturalness of the image. The mapped illumination is considered mainly to enhance details and preserve naturalness.

The reflectance R(x, y) and mapped illumination $L_b(x, y)$ are synthesized together to get the final enhanced image:

$$I^c(x, y) = R^c(x, y) \times L_b(x, y) \quad (20)$$

It is easy to verify the relative order for the pixels whose reflectance is fixed at 1 which does not change since the relative order of lightness in different local areas of the mapped illumination is same as that of the original illumination.

V. FLOW CHART

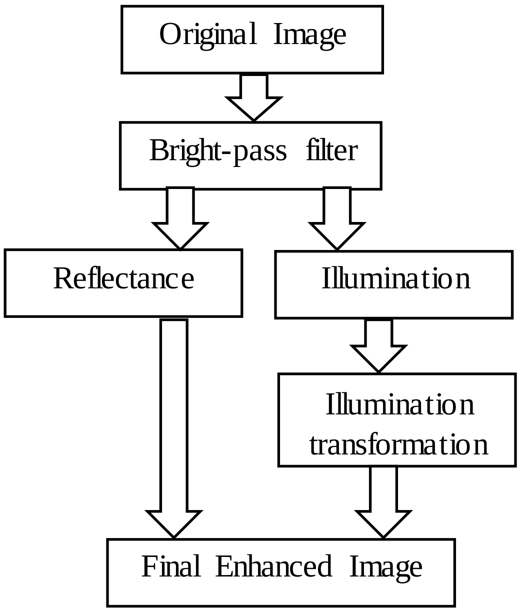

Fig.2. Flow chart of the implemented algorithm.

V. RESULTS & DISCUSSION

The implemented algorithm has been tested on the dataset of low contrast and high contrast gray-scale images. In this paper, four representatives are presented including Room, sea, building and girl images. These images are processed by this algorithm using BPF with and without using Block processing. The results of this algorithm in comparison with BPDHE [17] algorithm are presented in the results Fig.3 to 6 simultaneously.

BPDHE effectively preserves the lightness order of the input image. It is a global histogram equalization (HE) algorithm, which is disadvantageous to highlight the details in areas of low intensity. The algorithm implemented results in good performance compared to BPDHE algorithm.

This algorithm is implemented with and without using Block processing. In block processing, the processing is done by considering each block of the image separately where as in

general the overall image is considered. The results using Block processing achieves better performance compared to the results without using block processing. From the results, it can be seen that this algorithm preserves the naturalness of the image while enhancing the low contrast details. Form observing the results of the girl image, it can be said that there is no improvement for high contrast images using this algorithm. This algorithm works for low contrast images only.

(a) (b) (c) (d)

Fig.3. Results for Image Room (a) Original Image (b) BPDHE Image (c) Implemented algorithm without using Block processing (d) Implemented algorithm with using Block processing.

(a) (b) (c) (d)

Fig.4. Results for Image Sea (a) Original Image (b) BPDHE Image (c) Implemented algorithm without using Block processing (d) Implemented algorithm with using Block processing.

(a) (b) (c) (d)

Fig.5. Results for Image Building (a) Original Image (b) BPDHE Image (c) Implemented algorithm without using Block processing (d) Implemented algorithm with using Block processing.

(a) **(b)** **(c)** **(d)**

Fig.6. Results for Image Girl (a) Original Image (b) BPDHE Image(c) Implemented algorithm without using Block processing (d) Implemented algorithm with using Block processing.

CONCLUSION

Image enhancement plays an important role in image processing applications. In this paper, the algorithm is carried out using BPF and Bi-log transformation. This algorithm is implemented with and without using Block processing. Both the results are compared with BPDHE algorithm. This algorithm with Block processing results in better performance compared with others. This algorithm preserves the naturalness while enhancing the low contrast details.

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